PATENT
MAG04 P-1087

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Group	:	2621
Examiner	:	David J. Czekaj
Applicants	:	Kenneth Schofield, Mark L. Larson and Keith J. Vadas
Serial No.	:	10/643,602
Filing Date	:	August 19, 2003
For	:	VISION SYSTEM FOR A VEHICLE INCLUDING IMAGE PROCESSOR

DECLARATION OF DR. NIALL R. LYNAM UNDER 37 CFR §1.132

I, Niall R. Lynam, Ph.D., do hereby declare and state:

1. I am the Senior Vice President and Chief Technical Officer of Magna Mirrors of America, Inc. (a.k.a. Magna Donnelly Corporation, a.k.a. Donnelly Corporation, 49 West 3rd Street, Holland, Michigan 49423), and I have been with the company since the early 1980s. My responsibilities at Magna Mirrors/Magna Donnelly/Donnelly Corporation (hereafter "Donnelly") have included research and development of new products, including vehicular vision systems as well as technology and business management. I submit this declaration in relation to U.S. patent application Serial No. 10/643,602, invented by Schofield et. al ("Schofield"). I submit this declaration in response to, and necessitated by, the Office Action mailed by the United States Patent and Trademark Office ("USPTO") on February 24, 2010.

2. I make this declaration of my own knowledge and could and would testify competently as to the matters set forth herein, if called upon to do so by a court of law.

3. I graduated in 1975 from the University College Dublin receiving a Bachelor of Science degree in chemistry and mathematics and remained at the University College Dublin as a postgraduate student and was conferred with a Ph.D. in 1981. My doctoral thesis was on an opto-electronic topic and included optics and electronics developments.

4. I joined Donnelly Mirrors Ltd. (a subsidiary company of Donnelly) in 1980 as a research scientist.

5. In 1984, I transferred to Donnelly Corporation as a principal scientist in Applied Research. In 1985, I was appointed manager of Applied Research and, in 1986, I joined Donnelly's Corporate Management Team. In 1992, I was appointed Vice President, Corporate R&D. In 1995, I was appointed Senior Vice President, Chief Technical Officer. Throughout my career with Donnelly, I have been involved in the development of new products including vehicular vision systems and other optical, electronic and mechanical products for various areas of an automobile.

6. I hold numerous patents in the field of automotive products, several of which are related to vehicular vision systems, including United States Patent Nos. 4,712,879; 5,122,647; 5,285,060; 5,715,093; 5,929,786; 6,222,460; 6,353,392; 6,445,287; 6,534,884; 6,690,268; 6,806,452; 7,168,830 and 7,224,324.

7. The '602 patent application is one of several patent applications and patents relating to automotive vision systems owned by Donnelly.

8. I have reviewed the '602 patent application, and I have reviewed its prosecution history at the USPTO and its associated prior art. I have also reviewed the papers and art presented and considered in the present examination of the '602 patent application, including the Office Action dated February 24, 2010 and the references cited in the Office Action.

9. Prior to and contemporaneous with the priority filing to parent application, which issued as U.S. Patent No. 5,670,935 (based on U.S. patent application Serial No. 08/445,527, filed on May 22, 1995), I was responsible for Donnelly's Applied Research Department. Since the filing date, I have continued to be familiar with vehicular vision systems in general, and I am familiar with the commercial usage of vision systems on vehicles.

10. I am familiar with the state of the art as of the early '90s in the arena of vehicular vision systems in general and vehicular camera-based back-up systems in particular. I am also familiar with the extensive experimentation and testing undertaken by Schofield et al. and required to develop the inventions that led to the '602 patent application. I concur with Schofield's disclosure in the Background to the Invention of the '602 patent application that, as of

the early '90s, camera-based rearview vision systems for vehicles had not obtained commercial acceptance on the likes of the vehicles illustrated in the drawings.

11. In my opinion, a person that is of ordinary skill in the art of the subject matter of the Schofield Vision System would have a Bachelor's Degree in electrical engineering, or a Bachelor's Degree in mechanical engineering with experience in cameras and image processing and displays, or a Bachelor's Degree in science with experience in physics, or equivalent thereof. One of ordinary skill in the art would have at least two years of experience in the field of the subject matter, such as two or more years of experience in the field of automobile imaging systems or vision systems and/or automobile monitoring systems. One of ordinary skill in the art would be familiar with image capture devices or cameras and displays and associated parts and operation, including construction and sources of supply thereof. For example, one of ordinary skill in the art would be an engineer or technical person working at an automobile manufacturer or at a supplier of vision systems to an automobile manufacturer or comparable entity. At the time of the Schofield et al. invention, I was at least of ordinary skill in the art of the subject matter of the Schofield Vision System.

12. I understand that my Declaration will accompany Donnelly's response to the Office Action in the examination of the '602 patent application. I have reviewed that response in preparing my Declaration.

13. The claimed inventions of the '602 application encompass a vehicular vision system, including as exemplified by claims 50, 92, 99, 102 and 105:

> (i) a vehicle equipped with two or more image capture devices, said two image capture devices capturing images external of the vehicle, said two image capture devices having overlapping fields of view, (ii) said vehicle equipped with an image processor, wherein image data captured by said two image capture devices are processed by said image processor, (iii) said image processor producing a synthesized image from said image data captured by said two image capture devices, (iv) said synthesized image comprises a composite image of said image data captured by said two image capture devices without duplication of image

information, (v) said vehicle equipped with a display screen displaying said synthesized image, (vi) said synthesized image displayed as a single image on a single display screen that is viewable by a driver of said vehicle when the driver is normally operating said vehicle, (vii) wherein the displayed image displayed on said single display screen includes an image portion from an image captured by each of said two image capture devices.

I will hereafter in this Declaration refer to (i) through (vii) above collectively and combined together as the "Schofield Vision System."

14. Exhibit A attached hereto is a 1999 Society of Automotive Engineers (SAE) paper titled "Panoramic Electronic Rear Vision for Automotive Applications" and authored by Rich Hicks, Ken Schofield, Paul Tarno and Mike Veiseh of Donnelly Electronics. This SAE paper was presented at the International Congress and Exposition in Detroit, Michigan on March 1-4, 1999. The SAE International Congress and Exposition is a prestigious international Congress and Exposition and technical papers such as in Exhibit A are invited for presentation at Technical Sessions attended by engineers and interested persons drawn from the global automotive technical and business community. Page 3 of Exhibit A is reproduced to the right. This SAE paper (Exhibit A) is co-authored by Ken Schofield, one of the inventors of the '602 application, and shows how a displayed image comprises a synthesized image that provides a virtual image that shows the entire

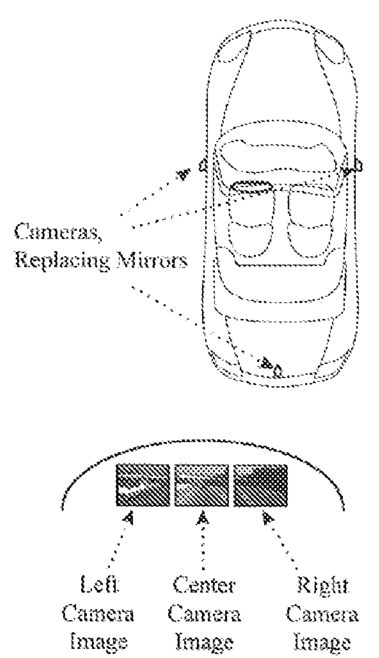


Figure 1. Camera Location and Multiple Display Option

Merged Image – Another option is to merge the three camera images into a single integrated image to be viewed on a single display. This approach is illustrated in Figure 2. In this example, three camera images are used to synthesize a virtual image that shows the entire scene to the rear of the vehicle. In this synthesized image the redundant information from the three images is eliminated. In addition, information from all three image sources is placed in the appropriate relative perspective providing drivers intuitive, visual information about their surroundings.

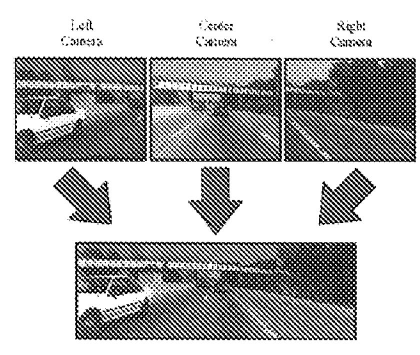


Figure 2. Merged Image Example

This architecture has the cost advantages of a single display while providing two distinct advantages.

- Full coverage of the rearward scene - eliminating any significant blindspots and the requirement for drivers to direct their eyes to specific locations
- Integration of all information relating to the rear scene into a single image - eliminating the need to check and integrate multiple sources of information

It is these advantages that more than compensate for the system's loss of depth cues and limited resolution, resulting in a cost effective improvement to traditional rear view systems.

scene rearward of the vehicle. As can be seen above, the synthesized image comprises a composite image of image data captured by two or more image capture devices without duplication of image information, and the synthesized image is displayed as a single image on a single display screen (see Merged Image of Figure 2 above), and the displayed image displayed on the single display screen includes an image portion from an image captured by each of the image capture devices (see the Left Camera Image, Center Camera Image and Right Camera Image of Figure 1 above). When the two or three images are merged and the synthesized merged image is displayed on the single display screen, the displayed image approximates a rearward view from a single location and may provide a substantially seamless view rearwardly of the vehicle.

15. Exhibit B attached hereto is a Ward's AutoWorld article dated May 1, 1998. Ward's AutoWorld is a well-known and widely accessed automotive publication with widespread circulation throughout the global automotive technical and business community. Exhibit B discusses, at page 2, Donnelly's development and production of a three camera vision system, which as two side cameras and a third rear camera, with the images captured by the cameras converged into one, which can be displayed for the driver on a screen on the instrument panel. The article states that "Combining the images into one central location could be an improvement."

16. Exhibit C attached hereto is a Donnelly 2000 Company Profile. This publication was broadly circulated by Donnelly around 2000 to interested members of the automotive technical and business community. Exhibit C discusses the GM Precept concept vehicle introduced in late 1999, which included a three camera vision system of the type disclosed and claimed in the '602 application. Exhibit C, at pages 3 and 4, states that "Donnelly's unique system is built around proprietary software that merges the digital images from three or more separate cameras into a single panoramic image. Through that image, drivers have a clear, unified view of the rear and sides of the vehicle."

17. Exhibit D attached hereto is a GM Opel Press Release dated January 5, 2001. This is a press release released by GM's Opel division. Exhibit D also discusses the GM Precept concept vehicle and Donnelly's vision system (which corresponds to the Schofield Vision

System disclosed and claimed in the '602 patent application). Exhibit D, at page 3, states: "So efficient is the Precept's shape that just the addition of conventional outside rear-view mirrors would increase drag by more than 17 percent. Consequently, the Precept employs two tiny cameras instead of outside rear-view mirrors which, when combined with a third rear-facing camera located inside the rear window, produce an integrated panoramic rear view on a reconfigurable LCD display easily viewed by the driver."

18. Exhibit E attached hereto is an article from www.theautochannel.com that touts the Donnelly PanoramicVision system on a Renault Talisman concept car at the 2001 Frankfurt Motor Show. This publication was broadly circulated and accessed by interested members of the global automotive technical and business community. Exhibit E states: "Donnelly's next generation PanoramicVision™ system is demonstrated on the Renault "Talisman" concept car. There are no mirrors on the car. Instead, this system digitally merges the images from three cameras to relay a seamless panoramic view of the area behind and around the vehicle. The view is displayed on a screen located on the upper part of the dashboard. The screen also provides information on navigation, the sound system, the heating and cooling system, and the vehicle's warning and security system."

19. Exhibits A-E are evidence of the pioneering development and commercial success of the claimed Schofield Vision System invention of the '602 application, as well as the praise and accolades it received when disclosed by leading automakers at prestigious international automotive shows on various concept cars. Thus, these Exhibits evidence the non-obviousness of the Schofield Vision System at least because, about 5 years or so after the filing of the parent of the '602 application, experts and automakers experienced in the field were sufficiently impressed with the Donnelly vision system that they included it in their highly anticipated concept vehicles, and experts and media pundits touted its uniqueness and the improvements and enhancements it would provide to vehicles. The commercialization and production of the Donnelly vision system, such as in the Precept and Talisman vehicles in 2000 and 2001, clearly evidence the commercial success of the Schofield Vision System. And the fact that, several years after the filing of the parent Schofield priority patent application, experts were still quick to praise Donnelly's vision system as pioneering and unique, which further evidences the

commercial success of the Schofield Vision System and the failure of others to invent and produce a vision system suitable for use in vehicles that would provide a single display of an image synthesized from multiple images captured by multiple cameras of the vehicle. The articles and publications of Exhibits A-E thus evidence the non-obviousness of the claimed invention of the '602 application.

20. The teachings and claimed subject matter of the '602 application have been important to the commercial success of such camera-based vision / display systems. In my opinion, Schofield's innovation of having the multiple images merged and a single image synthesized for display on a single display screen collectively and in combination with the other elements of the claimed invention provides an effective solution to the longstanding problem of providing information to a driver in a meaningful manner that does not distract the driver when he or she is driving the vehicle, such as during a reversing maneuver.

21. There is abundant evidence, such as is shown in Exhibits A-E, that the Schofield claimed invention of the '602 application was not obvious to one skilled in the art as of May 22, 1995. Such evidence includes the successful use of the synthesized image and single display screen with the multiple elements of the Schofield Vision System for the likes of the GM Precept concept vehicle and the Renault Talisman vehicle commercially successfully supplied by Donnelly. The Schofield Vision System, as claimed in the '602 application, satisfied a long-felt need. And the non-obviousness of the Schofield '602 claimed inventions is further evidenced by Donnelly's use on such vehicles.

22. When Renault, following the debut of the Precept and after seeing the accolades given to Donnelly's vision system, wanted to provide a rear vision system in its Talisman concept vehicle to be shown at the prestigious Frankfurt Motor Show, it was Renault's desire to have the proven performance and benefits of the Schofield Vision System invention (and not merely some increasing popularity of a particular vehicle model or the effectiveness of the marketing efforts or advertising employed) that drove to Donnelly's commercial success in being able to work with Renault and provide the vision system to Renault to begin with and that drove to Donnelly's commercial success in the selection of the Schofield Vision System for the Precept and Talisman vehicles. In terms of business awards by automakers, advertising or the like by

suppliers do not typically play a role in winning business, and thus the use of the Schofield vision system on the Precept and Talisman vehicles is based on the technical merits of the claimed Schofield vision system invention. The OEM market and supplier market is relatively small and extraordinarily competitive – so neither advertising, ties to the supplier, nor other similar business reasons have bearing on the choice of rear vision system for such applications.

23. While there may be many reasons a consumer may choose to buy a vehicle at a dealership, there is a reason that Renault chose to have the Schofield Vision System in its Talisman vehicles --- and that reason is that by the time Renault began to develop the Talisman vehicle, the Schofield Vision System had already been a proven success on the prior GM Precept vehicle.

24. The commercial success achieved by Donnelly with the Renault Talisman vehicles that use the Schofield Vision System is not the result of heavy promotion or advertising, or a shift in advertising, and is not the result of consumption by purchasers tied to the assignee of the present application (neither General Motors nor Renault is tied to Donnelly and neither General Motors nor Renault has a vested interest in the outcome of this patent prosecution), and is not the result of other business events beyond Renault's desire to use the proven Schofield Vision System. Renault wanted the proven success and reliability and performance of the rear vision system of the Renault Talisman vehicles to match that of the proven prior GM Precept rear vision system, and thus chose the Schofield Vision System for its Talisman vehicle.

25. It is my opinion that the use of the Schofield Vision System by the likes of General Motors and Renault is evidence of the commercial success of the presently claimed invention. The Schofield vision system was shown at prestigious events and the shown vision system utilized the Schofield Vision System, with the claimed elements of the claimed system being important elements in the success of the concept vehicles shown. To have the so selected and so used Schofield Vision System shown at such prestigious events and implemented as part of new pioneering vehicles, clearly evidences the pioneering and novel and non-obvious aspects of the Schofield Vision System. And the praise and accolades given by the experts (see Exhibits B, D and E attached hereto) upon review of the Schofield Vision System is further evidence of the pioneering and novel and non-obvious aspects of the Schofield Vision System.

26. It is my opinion that the high praise and accolades given to the Schofield Vision System is in and of itself strong evidence of the unexpected results of the vision system that is disclosed and claimed in the '602 patent application.

27. If anything, in my opinion, the other vehicle vision systems disclosed in the likes of the applied art of Secor and Nishimura and Tuck, constitute failed attempts by others to conceive and develop a rear vision system that would provide a display of a rearward view in a meaningful manner that would not distract the driver while the driver is operating the vehicle, such as during a reversing maneuver, and in accordance with the claimed subject matter. Otherwise, and logically, it would have been the likes of the applied art of Secor, Nishimura and/or Tuck that would have been used by leading automakers for their concept vehicles, and such would have occurred (but did not occur) years earlier than the filing date of the Schofield priority application.

28. Further, it is my opinion that the use of the Schofield Vision System on the likes of the concept Precept and Talisman vehicles, several years after the initial filing of the priority application, itself evidences the skepticism of experts for what went before, and thus reinforces the innovativeness of the claimed Schofield Vision System.

29. It is my opinion (as at least one of ordinary skill in the art at the time of the invention), that the abundance of secondary considerations evidenced above show that the combination of features that collectively and combined together constitute the Schofield '602 application claims would not in 1995 have been predictable to one of ordinary skill in the art. Indeed, the commercial success of what Schofield invented evidences the uniqueness and innovativeness of the Schofield Vision System, such as described and claimed in the Schofield '602 patent application.

30. The Office Action rejects the claims of the Schofield '602 application in view of various combinations of Secor, Fukuhara, Nishimura, Tuck and Kishi. It is my opinion (as at least one of ordinary skill in the art at the time of the invention) that Secor, either alone or in combination with Fukuhara or Nishimura or Tuck or Kishi or other prior art of record, does not

disclose or suggest or render obvious to one of ordinary skill in the art the claimed subject matter of the Schofield Vision System.

31. I have reviewed Secor, U.S. Patent No. 5,289,321, and note that Secor discloses multiple cameras and multiple display screens, with each of the display screens displaying images from a respective camera. It is my opinion that Secor clearly teaches towards use of a display screen to display images from only a single camera at a time, and thus teaches away from displaying a synthesized image displayed on a single display screen that is viewable by a driver of said vehicle when the driver is normally operating said vehicle, with the synthesized image being produced by an image processor from image data captured by two image capture devices, with the synthesized image comprising a composite image of the image data captured by the two image capture devices without duplication of image information, and with the displayed image displayed on the single display screen including an image portion from an image captured by each of the two image capture devices, such as is clearly included in the Schofield Vision System.

32. Clearly and unequivocally, Secor distinguishes its side-rear view camera 22 from its side-looking camera 34. This is plain from simply looking at the Figures of Secor (such as Figure 3, reproduced to the right), and it is also plain and unequivocal from the description of Secor and how Secor describes and distinguishes the function of camera 22 from the function of camera 34. Secor also discloses that the display screen 42 can be ***switched between*** the side-rear view camera assembly 22 and the side-looking camera assembly 34 (see column 5, lines 34-41 of Secor). For example, and as clearly disclosed in Secor, the "switching of the screens back from the camera assemblies 34 to the side camera assemblies 20 and 22 occurs automatically, for example, if the vehicle is shifted out of reverse into a forward speed" (see column 5, lines 37-41 of Secor). Thus, Secor's display screen 42 only discloses images from ***one*** of the cameras at a given time, and the images captured from ***either*** the side-rear view camera (22) ***or*** the side-looking camera (34) are shown on the display screen (42), but the system of Secor ***never*** shows images from ***both*** cameras ***at the same time on the same screen***.

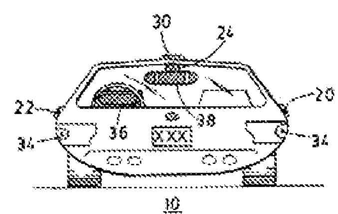
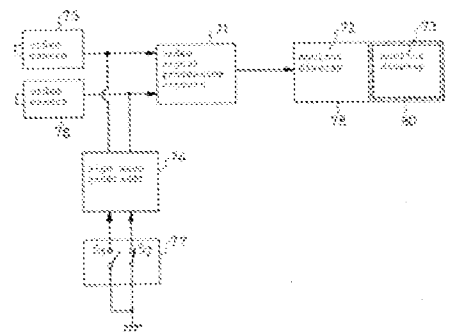


FIG. 3

33. I have reviewed Nishimura, U.S. Patent No. 4,713,685, and note that Nishimura discloses use of a wide display for displaying two separate, distinct and isolated images. The images are captured from opposite sideward facing cameras (see column 4, lines 36-41 of Nishimura). The separate images are played on both sides of the display, which is divided by a vertical center line (see column 2, lines 26-29 of Nishimura). To further separate and isolate the separate images from one another, a switch is responsive to a turn signal of the vehicle being operated and issues a signal for displaying a flashing sign on the frame part (80) of the display (78) at the respective separate image (72, 73). See column 7, lines 6-28, and Figure 7 of Nishimura, reproduced to the right.

FIG. 7



34. Thus, it is my opinion that Nishimura does not disclose or suggest a display screen displaying a synthesized image, with the synthesized image comprising a composite image of image data captured by two or more image capture devices without duplication of image information. To the contrary, Nishimura discloses two separate images of areas at opposite sides of the vehicle, with the displayed images providing distinct and separate views of distinct and separate regions exterior the vehicle, and with the displayed images clearly providing respective views from separate and distinct respective locations. It is my opinion that Nishimura thus teaches away from providing a synthesized image and display of the Schofield Vision System by Nishimura's teaching towards use of a wide display for displaying to separate, distinct, non-joined, isolated images in a side-by-side and separated and demarcated manner. Such a separate display of images is vastly different from the synthesized image that comprises merged together images captured by cameras with overlapping views to provide the driver with a single image of the area rearward of the vehicle, such as is clearly disclosed and claimed in the Schofield '602 application.

35. I have reviewed Fukuhara, U.S. Patent No. 4,653,316, and note that Fukuhara discloses an apparatus for detecting and analyzing cracks in a road surface, with a laser beam scanning apparatus for detecting road surface conditions, and with no display of captured video images. As disclosed in Fukuhara, the laser beam scanning apparatus includes two television

cameras that are directed at a 60 degree downward angle for catching the locus of the laser beam on the road surface and reflected light. The cameras have non-overlapping fields of view such that the cameras 22, 23 pick up the scanning loci 40 of the laser beam respectively in the range of positions P_1 - P_{2048} and P_{2049} - P_{4096} (see column 3, lines 56-60 and Figure 6 of Fukuhara, reproduced below).

FIG.6

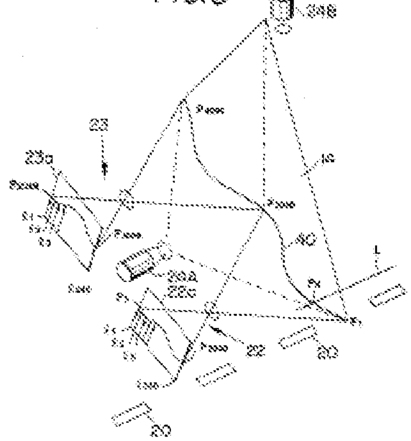
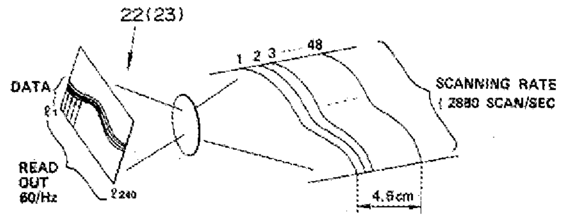


FIG.7



The cameras 22, 23 of Fukuhara capture the scanning locus of the laser beam for producing a transverse profile data of the road surface. This is shown in Figure 7 of Fukuhara (reproduced above), where the camera 22 (23) captures multiple transverse road profiles as the laser is scanned across the road surface in front of the camera (column 3, line 61 to column 4, line 7 of Fukuhara). The road profile data of the respective cameras are synthesized into a picture image representing the cross-sectional profile of the road (column 4, lines 22-24 of Fukuhara). The data regarding the transverse profile, cracks and the longitudinal profile are recorded on the VTR (column 6, lines 3-5 of Fukuhara), and "the data stored in the memory devices is converted into binary values in the processor 40 in accordance with a threshold value Ls shown in FIG. 13 so that the position of the crack is judged in accordance with data less than the threshold value Lc." (column 6, lines 16-20 of Fukuhara). "The result of judgment is displayed on display means, not shown such as a cathode ray tube" (column 6, lines 20-22 of Fukuhara).

36. The Office Action dated February 24, 2010 in the Schofield '602 patent application, at page 3, states:

> Fukuhara discloses "an image processor producing a synthesized image from the outputs of the image capture devices by at least one of: luminant blending, chrominant blending, dynamic range extending, pixel group compensation, anti-blooming, multiple exposure, image morphing compensation, or image warping compensation" (Fukuhara: figures 4 and 8; column 4, lines 13-26).

I disagree. I have reviewed Fukuhara and Fukuhara does not disclose such an image processor or such image processing techniques. Column 4, lines 13-26 of Fukuhara states:

> FIG. 4, the data read out from respective television cameras are applied to the synthesizing circuit 33, where the data are synthesized in a manner to be described later and then recorded on a VTR 35. The image pick-up surface has a performance of temporarily storing and integrating so that picture image data written on the picture pick-up surface one frame before are read out. The reading out of the data is performed in synchronism with the output signal from the optical sensor 19.
>
> The synthesizing circuit 33 synthesizes picture images read out from respective cameras 22 and 23 into a picture image representing the cross-sectional profile FIG. 8 shows the manner of the synthesis.

Thus, Fukuhara merely discloses synthesizing circuit that synthesizes data that are recorded on a VTR. There is no disclosure or suggestion in Fukuhara of an image processor producing a synthesized image from image data captured by two image capture devices with overlapping fields of view, with the synthesized image comprising a composite image of the image data captured by the two image capture devices without duplication of image information, and with a display screen displaying the synthesized image as a single image on a single display screen that is viewable by a driver of the vehicle when the driver is normally operating the vehicle, and with the displayed image displayed on the single display screen including an image portion from an image captured by each of the two image capture devices, such as included in the Schofield Vision System. Nor is there a disclosure or suggestion in Fukuhara of an image processor processing image data captured by image capture devices by at least one technique chosen from luminant blending, chrominant blending, dynamic range extending, pixel group compensation, anti-blooming, multiple exposure, image morphing compensation and image warping compensation, such as is also included in claims 50 and 109 of the '602 patent application.

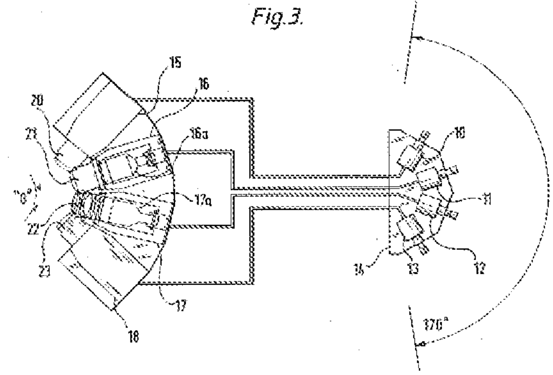
37. It is my opinion that there is no disclosure or suggestion in Fukuhara as to where this display means is located (it may be remote from the vehicle for later analysis of the processed data), and clearly there is no disclosure in Fukuhara that the display means displays images, since the display means is clearly for displaying the result of the judgment of the position of the crack. Thus, Fukuhara displays a result of judgment of the position of the crack based on processing of binary values of the data stored in the memory devices. There is absolutely no disclosure or suggestion in Fukuhara of displaying images on a video display screen, and particularly there clearly is no disclosure or suggestion in Fukuhara of a synthesized image displayed as a single image on a single display screen that is viewable by a driver of the vehicle when the driver is normally operating the vehicle. Fukuhara (at column 4, lines 13-26) merely states that "the data read out from respective television cameras are applied to the synthesizing circuit 33, where the data are synthesized in a manner to be described later and then recorded on a VTR 35." Fukuhara is wholly silent as to a disclosure or suggestion of an image processor that processes image data captured by the image capture devices by at least one technique chosen from luminant blending, chrominant blending, dynamic range extending, pixel group compensation, anti-blooming, multiple exposure, image morphing compensation or image warping compensation. Such processing clearly is not described in Fukuhara.

38. Fukuhara does not disclose or suggest such a vision system, but rather discloses a laser beam scanning apparatus for detecting road surface conditions. Fukuhara does not disclose or suggest a display of images on a display screen that is viewable by a driver of the vehicle when the driver is normally operating the vehicle. To the contrary, the television cameras of Fukuhara catch the locus of a laser beam on the road surface to determine the cross-sectional profile of the road surface. The data regarding the transverse profile are recorded on a VTR and the stored data is converted into binary values in the processor in accordance with a threshold value so that the position of a crack is judged in accordance with data that is less than a threshold value. Fukuhara discloses that the *result of the judgment* (of the position of the crack) is displayed on display means (see column 6, lines 3-23 of Fukuhara). Thus, nowhere in Fukuhara is there a disclosure or suggestion that images are captured and displayed to the driver of vehicle, and clearly there is no disclosure or suggestion in Fukuhara that a *synthesized image* (comprising a composite image of

merged image data captured by two image capture devices without duplication of image information in the manner claimed in the Schofield '602 application) is displayed on a single display screen that is viewable by a driver of the vehicle when the driver is normally operating the vehicle, with the displayed image displayed on a single display screen and including an image portion from an image captured by each of the two image capture devices, and nowhere is there a disclosure or suggestion of an image processor that processes image data captured by the image capture devices by at least one technique chosen from luminant blending, chrominant blending, dynamic range extending, pixel group compensation, anti-blooming, multiple exposure, image morphing compensation or image warping compensation, such as clearly disclosed and claimed in the Schofield '602 patent application.

39. I have reviewed Tuck, U.S. Patent No. 4,772,942, and note that Tuck discloses a display system for a tank that includes individual display units mounted side-by-side, each having a respective television camera associated therewith so that a substantially continuous picture of at least part of the surrounding panorama can be reconstructed and viewed by an observer. See, for example, the Abstract and Figure 3 of Tuck, reproduced to the right. As can be seen in Figure 3 of Tuck, each camera 10, 11, 12, 13 is associated with a respective display generator 15, 16, 17, 18, which display the respective images to the observer "O" through respective magnifying lenses 20, 21, 22, 23. There is no disclosure or suggestion in Tuck of a display system that displays a composite image synthesized from image data captured by the image capture devices without duplication of image information, and with the display system displaying the composite image on a *single* display screen of the vehicle. Nor is there a disclosure or suggestion in Tuck of the display system displaying a displayed image on a single display screen that includes an image portion from an image captured by each of the image capture devices or cameras. Moreover, it is my opinion that Tuck would teach one of ordinary skill in the art away from such a vision system by its teaching that each of the individual display units has a respective television camera associated therewith, such that images captured by each television camera are displayed on their associated

Fig.3.



display unit such that the displayed image on one of the individual display units cannot have an image portion from an image captured by each of the image capture devices.

40. Thus, it is my opinion (as at least one of ordinary skill in the art at the time of the invention) that none of the cited references discloses or suggests a single display screen displaying a synthesized image, with the synthesized image comprising a composite image of image data captured by two or more image capture devices without duplication of image information, and with the displayed synthesized image including an image portion from an image captured by each of two image capture devices having overlapping views, such as clearly included in the Schofield Vision System. As shown in Exhibit A (and see paragraph 14 above), such a displayed synthesized image may provide a substantially seamless view exterior or rearwardly of the vehicle, with the displayed image approximating a view from a single location.

41. In the Office Action dated February 24, 2010, the Examiner states that it would have been obvious to combine Secor with Fukuhara and/or Nishimura and/or Tuck to arrive at the claimed invention of the '602 application. I disagree. None of the cited references disclose or suggest a synthesized image as claimed. Secor discloses a display screen that displays images from only a single camera at a time, while Nishimura discloses a wide screen that displays separate images thereon, and Fukuhara does not disclose a display for viewing by the driver of the vehicle while the driver is driving the vehicle. It is my opinion (as at least one of ordinary skill in the art at the time of the invention), that, were one of ordinary skill in the art to look to the cited references (without also referencing the disclosure of the Schofield '602 application), one would <u>not</u> be led to the Schofield Vision System as described and claimed in the Schofield '602 application, but would rather be led to providing a display system for displaying separate individual images from one or more cameras with no synthesizing or merging of images captured by the one or more cameras of the vehicle.

42. In my opinion (as at least one of ordinary skill in the art at the time of the invention), neither Secor nor Fukuhara nor Nishimura nor Tuck, either alone or in combination with one another or other of the cited prior art, discloses, suggests or renders obvious Schofield's claimed subject matter relating to an image processor producing a synthesized image from image data captured by two image capture devices with overlapping fields of view, with the synthesized

image comprising a composite image of the image data captured by the two image capture devices without duplication of image information, and with a display screen for displaying the synthesized image, and with the synthesized image displayed as a single image on a single display screen that is viewable by a driver of said vehicle when the driver is normally operating said vehicle, with the displayed synthesized image that is displayed on the single display screen including an image portion from an image captured by each of the two image capture devices. As discussed above, such a displayed synthesized image may provide a substantially seamless view rearwardly of the vehicle that approximates a view from a single location. Such a synthesized image and display are not disclosed or suggested in the references applied by the Examiner in the Office Action or other prior art of record.

43. In my opinion, the Schofield '602 application is a pioneering and technically comprehensive teaching in its field. Within its eleven columns of specification and eleven figures (all filed in May 1995) are to be found many of the features of commercial multi-camera systems with graphic overlays only now, over a decade later, entering the market. Taking as an illustrative example the Donnelly PanoramicVision™ system and display, Schofield teaches use of such image synthesizing and merging to provide an exterior view to the driver of the vehicle at a single display in the vehicle. In my opinion (as at least one of ordinary skill in the art at the time of the invention), that this feature is only relatively recently being used on concept vehicles, such as is shown in Exhibits C, D and E, further evidences that the Schofield '602 application is a pioneering disclosure in this field.

44. Regarding the Examiner's rejection in the Office Action mailed by the USPTO on February 24, 2010 of independent claims 50, 92, 99, 102 and 105, I respectfully traverse at least because Secor, Fukuhara, Nishimura and Tuck (taken alone or in combination) are utterly devoid of a disclosure or suggestion that their systems have a display screen that displays a synthesized image that is synthesized from image data captured by two image capture devices with overlapping fields of view, with the synthesized image comprising a composite image of the image data without duplication of image information. Nor do these references disclose or suggest such a synthesized image displayed as a single image on a single display screen that is viewable by a driver of said vehicle when the driver is normally operating said vehicle, with the

displayed synthesized image that is displayed on the single display screen including an image portion from an image captured by each of the two image capture devices. As discussed above, such a displayed synthesized image may provide a substantially seamless view exterior of the vehicle and may approximate a view from a single location.

45. As one of at least ordinary skill in the art, it is my opinion that Secor, either alone or in combination with Fukuhara, Nishimura, Tuck and/or Kishi, fails to disclose or suggest to one of ordinary skill in the art at the time of the invention, the Schofield Vision System, as claimed in the '602 patent application. For example, none of the applied references disclose or suggest an image processor, wherein image data captured by image capture devices having overlapping fields of view are processed by the image processor, with the image processor producing a synthesized image from the image data captured by the image capture devices. Nor do the applied references disclose or suggest, for example, such a synthesized image comprising a composite image of the image data captured by the image capture devices without duplication of image information. Nor do the applied references disclose or suggest, for example, a display screen displaying such a synthesized image. Nor do the applied references disclose or suggest, for example, such a synthesized image displayed as a single image on a single display screen that is viewable by a driver of the vehicle when the driver is normally operating the vehicle. Nor do the applied references disclose or suggest, for example, such a displayed image displayed on such a single display screen including an image portion from an image captured by each of the image capture devices. With respect to the rejection of independent claims 92, 99 and 102, none of the applied references disclose or suggest a three camera system having a center image capture device with a field of view that overlaps the fields of view of each of two opposite side image capture devices, and with a display system that displays a composite image synthesized from image data captured by the image capture devices without duplication of image information, and with the displayed image including an image portion from an image captured by each of the side and center image capture devices. Thus, it is my opinion (as at least one of ordinary skill in the art at the time of the invention) that the Schofield Vision System, as disclosed in the Schofield '602 patent application and exemplified in the claims of the Schofield '602 patent application, is not disclosed or suggested or rendered obvious by the combination of

references applied in the Office Action dated February 24, 2010 in connection with the Schofield '602 patent application.

46. In my opinion (as at least one of ordinary skill in the art at the time of the invention), that the results that would have been expected from the combinations of references applied in the Office Action dated February 24, 2010 would be to have a display means that displays judgment or analysis information, such as taught by Fukuhara (not images for viewing by a driver of the vehicle while operating the vehicle), or to have a separate display for each respective camera (such as taught by Secor and/or Tuck) or a display that switches between cameras so that an image from only one camera is displayed on the display at a given time (such as taught by Secor), or to have two separate and distinct images (and not a synthesized composite image) displayed side-by-side and isolated or separated on a wide screen to provide views of the opposite side regions exterior the vehicle on the wide screen (such as taught by Nishimura). It is my opinion (as at least one of ordinary skill in the art at the time of the invention) that it would clearly have been unexpected to one of ordinary skill in the art, armed with the proposed combination of applied references, to provide a single display screen for displaying an image synthesized from image data captured by two or more cameras, with the synthesized image comprising a composite image of the image data without duplication of image information, and with the displayed image displayed on the single display screen including an image portion from an image captured by each of the two image capture devices. Plainly, since an artisan armed with Secor would be switching the display between the cameras, it is my opinion (as at least one of ordinary skill in the art at the time of the invention) that there would not have been a motivation to combine the teachings of Secor with those of Nishimura (separate images on display) or Fukuhara (laser beam scanning apparatus for detecting road surface conditions, with no display of captured images).

47. In summary, and as one who was active and of ordinary skill in this art back in the early to mid 1990s, it is my opinion, and as factually evidenced above, that the combination of features that collectively and combined together constitute the claims 50-52, 56, 58, 62, 67 and 92-109 and new claims added in the Applicants' response to the Office Action in this examination of the Schofield '602 patent application is more than a predictable use of prior art

elements according to their established functions. For example, it is a fact as evidenced above, and is not speculation, that Secor clearly, literally and consistently discloses use of a display to display only one image from one camera at a time, whereas in sharp contrast, the claims of the Schofield '602 patent application include a synthesized image from multiple images captured from multiple image capture devices or cameras. Likewise, it is a fact as evidenced above, and is not speculation, that Nishimura clearly, literally and consistently discloses use of a wide display to display two separate, non-merged and non-synthesized images from opposite sideward viewing cameras, whereas in sharp contrast, the claims of the Schofield '602 patent application include a synthesized image from multiple images captured from multiple image capture devices or cameras having overlapping fields of view and with the images captured by the cameras merged in the claimed manner and without duplication of image information. Likewise, it is a fact as evidenced above, and is not speculation, that Fukuhara clearly, literally and consistently discloses use of an apparatus for detecting and analyzing cracks in a road surface, with a laser beam scanning apparatus for detecting road surface conditions, and with no display of captured images for viewing by the driver of the vehicle, whereas in sharp contrast, the claims of the Schofield '602 patent application include a synthesized image from multiple images captured from multiple image capture devices or cameras having overlapping fields of view and without duplication of image information, and with the images captured by the cameras merged in the claimed manner and displayed on a single display for viewing by the driver of the vehicle when the driver is normally operating the vehicle. Back in the early '90s, CMOS camera technology and corresponding image processing techniques were only emerging in automotive systems and Ken Schofield, one of the inventors of the Schofield '602 patent application, was recognized in the early '90s as a pioneer in the use of CMOS camera technology in automotive vision systems.

48. The abundance of secondary considerations evidenced above, and such as is summarized above, show that the combination of features that collectively and combined together constitute the Schofield '602 patent application claims would not in 1995 have been predictable or obvious to one of ordinary skill in the art. In my opinion (as at least one of ordinary skill in the art at the time of the invention), the evidence presented above shows that one of ordinary skill in the art could not have arrived by known methods at the combination of

features that collectively and combined together constitute the Schofield Vision System as exemplified in the Schofield '602 patent application claims. The various elements in the various combinations of features that collectively and combined together constitute the Schofield Vision System do not merely perform the function that each element performs separately. This is evidenced such as by the incorporation of Schofield elements, and not those of Secor or Fukuhara or Nishimura or Tuck, into the likes of the camera-based vision systems shown in Exhibits C, D and E. Given that prior artisans (prior to Schofield et al. in 1995) tried and failed to provide a satisfactory camera system for providing a display of rearward information in a meaningful manner that did not distract from the driver's task of driving the vehicle, the commercial and unique success of the Schofield elements itself constitutes an unexpected result.

49. All statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true. I understand that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and that such willful false statements may jeopardize the validity of any patent that may issue from United States Patent Application Serial No. 10/643,602.

Dated: August 24 2010

Niall R. Lynam, Ph.D.

LYNAM EXHIBIT A

SAE TECHNICAL
PAPER SERIES

1999-01-0655

Panoramic Electronic Rear Vision for Automotive Applications

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Donnelly Electronics

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International Congress and Exposition
Detroit, Michigan
March 1-4, 1999

400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (724) 776-4841 Fax: (724) 776-5760

ISSN 0148-7191

Printed in USA

1999-01-0655

Panoramic Electronic Rear Vision for Automotive Applications

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ABSTRACT

Advances in electronics technology have opened numerous opportunities for new automotive products. One emerging area is the use camera systems to replace traditional rear vision systems in automotive applications. This paper will discuss the advantages of such systems, what technical advancements have led to the feasibility of such systems, and an example implementation of an electronic rear vision system.

INTRODUCTION

Advances in camera, optics, and display technology have made it feasible to develop cost effective closed circuit TV systems for automotive applications. One function to which these systems may be applied is to supplement or replace existing, mirror-based, rear vision systems on vehicles.

Replacing, or even supplementing, mirror-based rear vision systems should not be undertaken lightly. The functionality and ergonomics of the rear vision system directly affect the safety and comfort of the driver, and a poorly implemented camera-based system may detract from both. On the other hand, a properly designed camera-based system can reduce driver workload and enhance safety. The key to this is providing an intuitive representation of the information available from the cameras that can allow drivers to be effortlessly aware of their surroundings.

On the positive side, replacing mirrors with miniature cameras can have a positive impact on vehicle performance. Correctly implemented, camera systems can reduce the weight of the vehicle while reducing its aerodynamic. This can result in significant improvements to fuel efficiency.

BACKGROUND

In order to be successful, camera-based vision systems must significantly improve the driver's comfort and safety. While camera systems have several significant disadvantages when compared to traditional mirror-based systems, camera systems offer tremendous flexibility in the presentation of the information to the driver. The key to success, therefore, is finding a presentation method that offers benefits that outweigh the system's limitations.

CAMERA SYSTEM FEATURES – Camera-based vision systems have a variety of features, some of which are advantageous and some of which are detrimental. The key to a successful system implementation is developing an architecture that utilizes the advantages of camera-based systems to more than compensate for the disadvantages. The following sections describe several of the key features of a camera-based system and how they compare to mirror-based systems.

Resolution – The resolution of a mirror-based system significantly exceeds the human eye's ability to resolve features and objects. The resolution of a camera-based system is, unfortunately, a cost versus performance trade. This trade affects the sensor, any processing electronics and the display. While it may someday be feasible to provide a camera system with resolution comparable to a mirror system, current systems are severely limited in their performance.

A successful implementation must, therefore, offer sufficient resolution for drivers to easily perform their task, while offering additional benefits to compensate for the loss of resolution.

Field of View – The ability of a camera system to cover a wider and more complete field of view than a mirror system is one of its key advantages. While a mirror-based system is limited by obstructions between the driver and the rearward scene (vehicle pillars, passengers, etc) cameras can be placed on the exterior of the vehicle wherever necessary to cover the required field of view. A second limitation of a mirror system on the field of view is the amount of image distortion the driver can accommodate. The larger the distortion, the larger the resulting field of view. Camera-based systems can either use multiple cameras, or provide electronic distortion correction that can result in a large field of view without perceptible image distortion.

Depth Perception Cues – Humans use a variety of cues to determine the relative distance between themselves and an object. The drivers will rely on several of these

cues at any time to make determinations regarding relative and absolute distances between their vehicle and navigational obstacles. While the drivers can use any of these cues to some extent for any distance, they will tend to rely more on some cues than others depending on the distance to the object. Some of these cues, and the ranges that they will tend to be most significant, are summarized in the following table:

Table 1. Depth Perception Cues

Cue	Description	Object Distance
Stereoscopy	The use of perspective differences between the images perceived by the left and right eyes to determine the distance between the observer and an object	0 – 1 m
Depth of focus	The use of eye focal depth to determine the relative distance between two objects	0 – 30 m
Relative size	The comparison of the perceived size of objects with apriori knowledge of object to determine relative distance	10m - Infinity
Geometric perspective	The comparison of relative motion between objects in the field of view	10m - Infinity

While driving, the operator is required to determine the relative distance between his vehicle and others within the range of 1 meter to 50 meters. In this range, the driver will rely on both depth of focus, relative size, and geometric perspective. While both mirror and camera systems provide relative size and geometric perspective cues, the camera system falls short on depth of focus.

The mirror system simply folds the optical path of the image. This in essence maintains the optical distance, with some small error, between the driver and the object under observation. The camera system re-images the scene and provides the entire scene at a fixed focal depth that is determined by the display. The driver is, therefore, forced to rely solely on relative size to determine distances.

The camera system can, however, provide additional cues. Graphical depth cues can be added to the display to aid in the determination of relative distances. Lines can be overlaid on the camera scene indicating the distance from the vehicle. Objects behind the cue are further from the vehicle than the calibrated distance while objects intersecting the cue are closer. Clever and intuitive depth cues must be used in camera systems to compensate for the loss of depth of focus cues.

Image Presentation – It is in the area of image presentation that camera systems have significant advantages over mirror-based systems. Given the state of the art in today's processing technology, it is a straightforward matter to warp, scale, rotate and translate camera images to whatever extent is necessary to provide an intuitive, easily understood image to the driver. In addition, camera systems offer flexibility in the location of the information in the driver's field of view. Mirrors, by their very nature, dictate the location of the information.

Night Performance – Night time driving represents the most challenging environment for rear vision systems. The system must cope with headlights that are extremely bright while presenting information on roads that are poorly lit. In addition, the rear vision system has a potential for interfering with the driver's forward field of view by introducing glare sources that can interfere with the driver's ability to adapt to a dark forward field of view.

Mirror systems have traditionally only addressed night performance and glare sources with a simple prism mechanism on the interior mirror. It is only recently that mirrors have been introduced that can automatically darken to adapt to changing lighting conditions. These, electrochromic, mirrors have been applied to both interior and exterior rear view mirrors with good results.

Unfortunately, the electrochromic mirror technology is limited in its response to quickly changing lighting conditions. In addition, the control mechanisms applied to these systems are limited in their complexity and the entire mirror is darkened uniformly.

Camera systems have two advantages over electrochromic and prism technologies. The first is that the display luminance and image contrast are independent. The display luminance can be set to match the luminance of the drivers forward field of view regardless of the luminance of the rear scene. This results in a reduction of the driver's eye misadaptation that cannot be matched by a mirror system.

The second advantage is that the image contrast may be manipulated differently for different regions of the image. Areas where the image is extremely bright can be dimmed, while areas that are poorly lit may be amplified. This can result in information being provided to the driver that is unavailable using mirror-based systems.

SYSTEM ARCHITECTURE OPTIONS – Presenting information to the driver in the most intuitive fashion possible is the primary consideration in defining the architecture of a camera-based rear vision system. The architecture must play on the strengths of the camera system sufficiently to more than compensate for the resulting loss of resolution and depth of focus cues. Three options are described in the following sections.

Multiple Displays – The most straightforward approach to using cameras to replace mirrors is to simply place a camera at each outside mirror location and one on the rear of the vehicle and tie each camera video to a display. This is illustrated in Figure 1. This approach has been

demonstrated in a number of concept vehicles including several demonstrated at the 1998 Detroit Autoshow.

The advantage of this approach is that it is straightforward in its implementation and closely mimics the behavior of the traditional mirror systems with which most drivers are already familiar.

There are two major disadvantages to this approach. The first is that the most expensive component in the camera system is the display and this approach requires multiple displays. This can result in a system that is not particularly cost effective.

The second disadvantage is that the information is not presented in a particularly intuitive fashion. Drivers are required to scan multiple images that contain redundant information and integrate that information in order to understand their surroundings. This provides little advantage to drivers in terms of ease of use and in fact may be detrimental to their performance as depth cues and resolution are reduced.

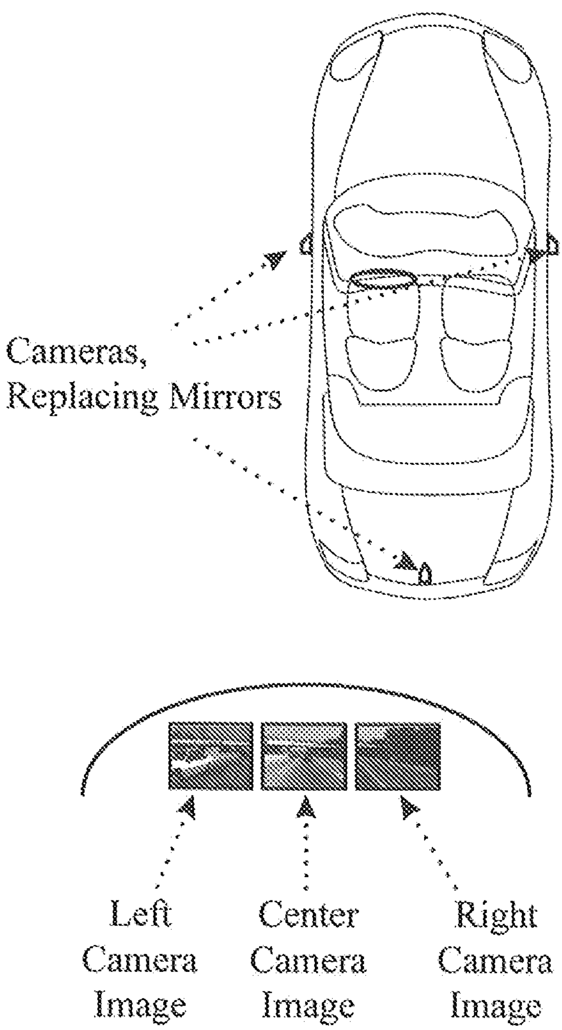


Figure 1. Camera Location and Multiple Display Option

Single Display – One approach to reducing the cost of the camera system is to display all three images on a single, larger display. While the elimination of two displays reduces system cost, it does little to improve the driver's perception of the system. The driver must still integrate information from multiple windows in order to make a decision about the environment. The use of a single display may be detrimental to the ease of use of the system as flexibility in the location of the three camera images is lost.

Merged Image – Another option is to merge the three camera images into a single integrated image to be viewed on a single display. This approach is illustrated in Figure 2. In this example, three camera images are used to synthesize a virtual image that shows the entire scene to the rear of the vehicle. In this synthesized image the redundant information from the three images is eliminated. In addition, information from all three image sources is placed in the appropriate relative perspective providing drivers intuitive, visual information about their surroundings.

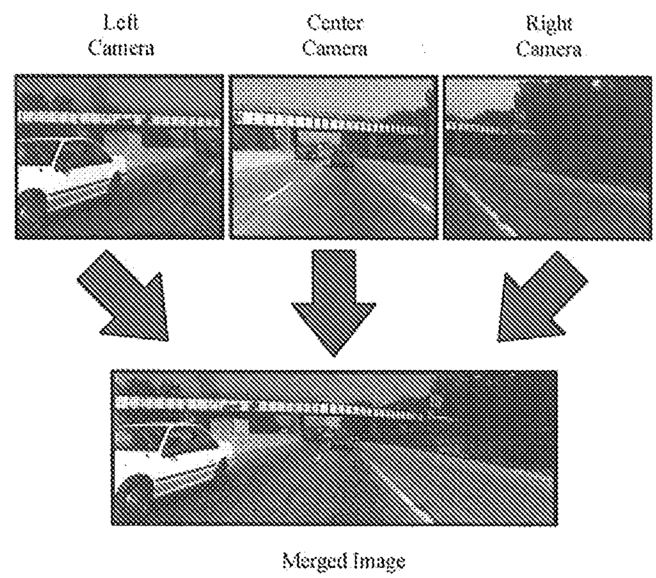


Figure 2. Merged Image Example

This architecture has the cost advantages of a single display while providing two distinct advantages:

- Full coverage of the rearward scene - eliminating any significant blindspots and the requirement for drivers to direct their eyes to specific locations
- Integration of all information relating to the rear scene into a single image - eliminating the need to check and integrate multiple sources of information

It is these advantages that more than compensate for the system's loss of depth cues and limited resolution, resulting in a cost effective improvement to traditional rear view systems.

PERFORMANCE REQUIREMENTS – Given a specific architecture, there are two performance factors that significantly impact the cost effectiveness of a camera-based system: Field of View and Resolution. The affect of each of these factors is described in the following sections.

Field of View – One of the major contributors to safe driving is the availability of visual information. The most important source of visual information in normal driving is within the driver's direct forward field of view. However, much important information is contained within the balance of the driver's surroundings or secondary field, particularly in multi-lane, high traffic density situations where lane maneuvers are frequent. The goal of a rear vision system is to provide a field of view that contains all of the important information within the rear view. Typically mirror systems do not provide a field of view that includes all the areas of greatest importance within the rear field, resulting in well known "blind spots." The goal of any camera-based rear vision system should be to clearly improve the rear field of view beyond that available through conventional means, and should ideally include all the secondary field areas of greatest importance.

Safe driving requires that maximum attention is paid to the forward view, and therefore information required from the rear view should be acquired in the shortest possible time. Several studies have focused on the time required to extract information from rear vision systems. In a test in which drivers were requested to make lane change maneuvers only when sufficient information had been acquired to ensure a safe maneuver, various rear vision systems were compared by measuring the time spent in acquiring rear view information and reporting it as a percent of maneuver time. This time included any head movement to acquire supplementary information that was not available through the mirror system.[1]

For a 32° field of view (FOV) inside mirror and 25° FOV left hand outside mirror, information acquisition took 50.6% of maneuver time. For the above system with an additional right hand convex 25° FOV outside mirror the acquisition time dropped to 45.9%. For a 72° FOV periscope system the acquisition time reduced further to 32.4%. We concluded that, in order to minimize acquisition time, the secondary fields of view should be presented in a single location, ideally as a continuous image, such that information may be obtained in a single rather than multiple glances. The single presentation also eliminates the need to "piece together" images - possibly requiring additional confirming glances.

Figure 3 shows the normal field of view of a pair of human eyes. In Figure 3, lines have been superimposed to represent typical positions of the major limits to a car driver's field of view such as the top of the windshield, the hood line, and the 'A' pillars. If we also consider the bifocal user, the most appropriate location for a single rear view image is directly ahead of the driver and just below the hood line such that the forward field of view is not impaired. It is desirable to size the rear view image such that it remains within the area normally viewed by both eyes.

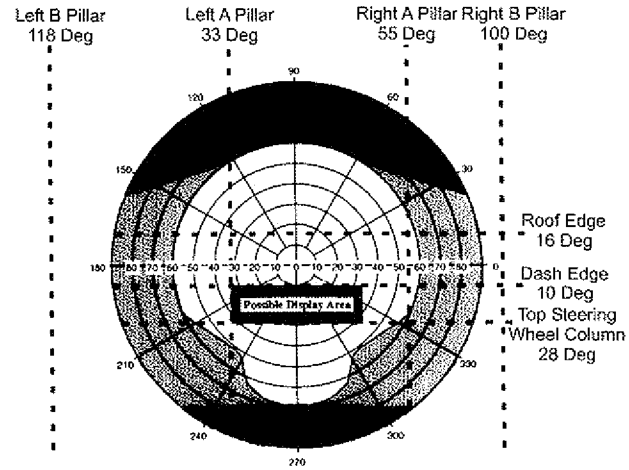
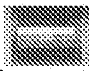


Figure 3. Driver Field of View

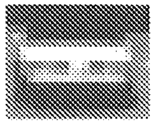
Resolution and Visual Acuity – Visual acuity may be subdivided into resolution acuity and recognition acuity. In a rear vision system we are concerned with recognition acuity but it is useful to consider system requirements initially based on resolution. The human eye is equipped with photoreceptors which subtend approximately 0.5 arc minutes. This sampling rate corresponds to an ability to resolve the viewed scene to about 1 arc minute in good lighting conditions. Figure 4 shows images pixilated to various degrees, changing the information content consistent with the view of objects at various distances, and then scaled to a constant pixel size, providing a realistic simulation of how objects are perceived at various distances. Sufficient information is required to allow a driver to recognize and make good judgment about other road users at least at a distance which allows other road users take safe corrective action. A target recognition performance for a driver using a camera vision system can be determined based on a typical driver reaction time and stopping distance for a vehicle traveling at 160 km/hr (100 mph) and the ability to recognize a vehicle when pixilated at approximately 100 mm square. This analysis leads us to a resolution design target of 6 arc minutes, or a camera sampling capability of 3 arc minutes.

In order to optimize system performance, display resolution should match the camera capability, and the display should be sized and positioned to match the human ability to resolve the displayed pixilated image. In addition, the display size/resolution should provide image sizes that match the driver's expectation of relative object size vs. distance. We have established above that the camera should sample the object scene at a minimum of 3 arc minutes. It is assumed that, if cost is to be minimized, the display will be linked to the camera output with a pixel to pixel correspondence. In turn each pixel of the display should subtend no less than 1 arc minute of driver view to

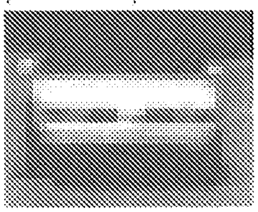
avoid any system loss, and should probably match the sampled resolution of 3 arc minutes as closely as possible to maintain distance perception cues. Thus, for example, if the displayed horizontal rearward field of view is 60°, the display should contain 1200 pixels in each horizontal row, and if the display is positioned 60 cm from the driver's eyes, the horizontal dimension of the display should be no less than 20 cm. Note that this results in a practical 60 pixels per cm of display.



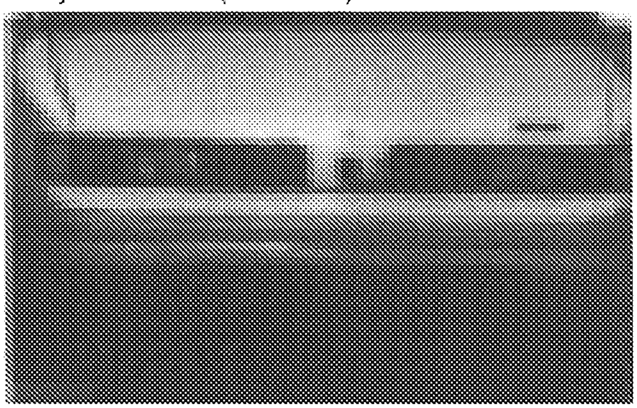
Object at 1 km
(0.64 miles)



Object at 0.5 km
(0.34 miles)



Object at 325 m (0.20 miles)



Object at 100 m (0.06 miles)

Figure 4. Image Resolution Example

PAST WORK

Our first efforts in the application of cameras to automotive rear vision centered around the use of multiple cameras and displays to directly replace the exterior rear view mirrors. After a short period of experimentation we discovered the drawbacks of this approach and began the development of a system that would combine the three camera images onto a single display.

GOALS – The purpose behind developing the prototype system was to provide us with a platform that we could use to verify the utility of the thee camera, panoramic rear vision system. In addition, the development platform was to be used to experiment with the effect of various performance factors on the perceived quality and usefulness of the system.

This being the case, practical considerations such as system size, power consumption, and maturity of appearance were not major design considerations. The development efforts focused instead on providing a high degree of modularity and flexibility in the nature and content of the image displayed to the driver. In addition, we recognized that the electronics and display technology required to implement a cost effective system would not be available for several years. This led us to the decision to apply more processing electronics to the problem than we would have had we been focused on developing a system that was nearer to production.

DEVELOPMENT PLATFORM DESCRIPTION – A photograph of the development platform, including an overlay showing the location of the cameras and the field of view covered by each camera, is shown in Figure 5. As you can see from the picture, we selected a minivan as our development vehicle. This allowed us to implement a bulky system while locating the electronics within the interior of the vehicle and made wiring of the system simpler.

A block diagram of the development platform is shown in Figure 6. The three cameras required for the panoramic vision are fed into a data processing module. In addition, a fourth sensor is fed into the data processing module. This fourth sensor is used as a reversing aid and shows a field of view below what is visible looking through the rear windscreen from the driver's seat.

In addition to the video images, vehicle status information such as speed and gear shift position are fed into the data processing module. The data processing module uses this information to control the image processing calculations needed to combine the three images into a panoramic scene.

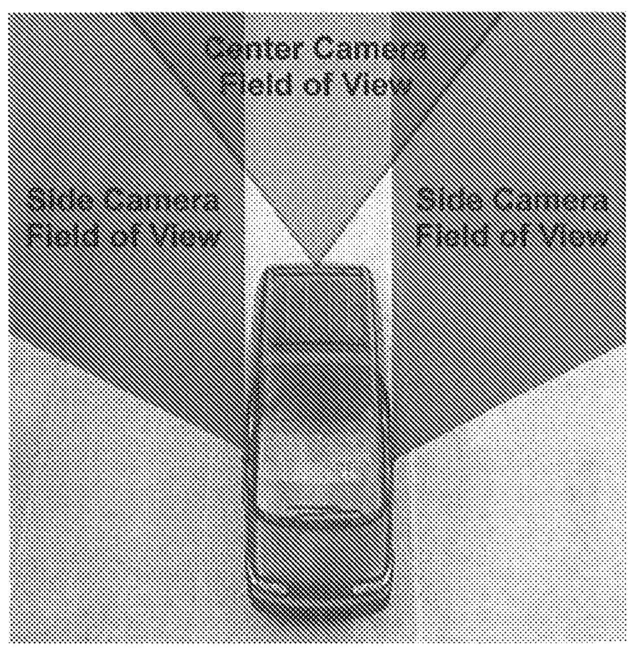


Figure 5. Development Platform

The system displayed the merged video on a 12.7 cm diagonal LCD mounted in front of the driver, just below his forward field of view during normal driving. In addition to the video, the system displayed rudimentary vehicle

status information such as turn signal and speed information.

CURRENT WORK

While the development platform was successful in demonstrating the feasibility and utility of a panoramic rear vision system, it did not do so using techniques consistent with production goals. Since the completion of the development platform, there have been significant increases in the performance and density of digital signal processing electronics, miniature CMOS cameras, and display technology. We felt that it was feasible to develop a prototype system that would closely resemble in form, fit, and function a production system.

GOALS – The primary goal of our current activities is to leverage advances in technology to develop a panoramic rear vision system and integrate it into a test vehicle. In this effort, size, power and image quality are primary considerations.

NEW SYSTEM DESCRIPTION – In the development of the new system we set stringent power, size and weight requirements. This gave us some flexibility in the selection of a test vehicle and we chose a sedan with conservative styling and a CAN network. The CAN network was used to transmit vehicle status information to the electronics as well as to provide for in-vehicle reprogramming of the system software.

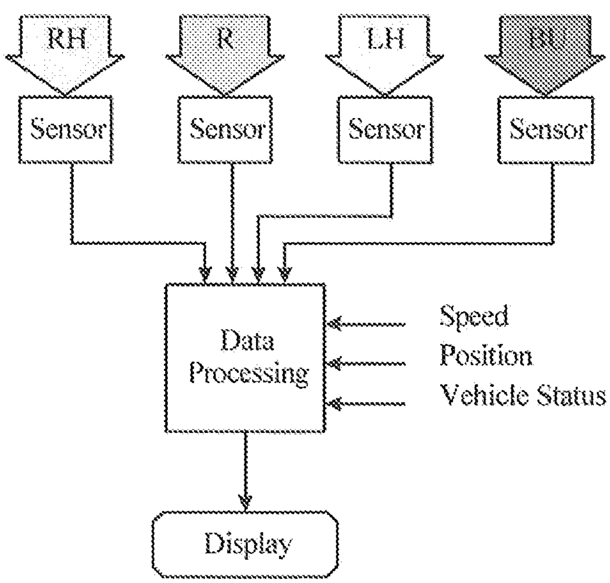


Figure 6. Development Platform Block Diagram

A block diagram of the system is shown in Figure 6. This system uses four cameras - three for the panoramic vision and a fourth as a reversing aid. The two cameras in the rear of the vehicle are connected to a small module that selects one of the video signals and transmits it to the main module over a high speed, serial link. This improved the flexibility we had in running the signals through the vehicle as it both eased cable length restrictions and reduced cable size.

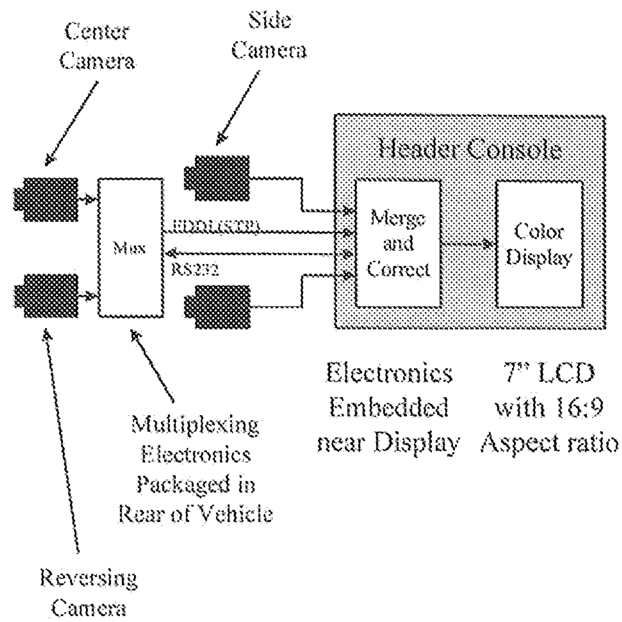


Figure 7. New System Block Diagram

The main electronics module, including the display, was packaged into the header console - replacing the interior rear view mirror. We selected this location for two reasons:

- This location minimizes the effect of the system on the interior styling of the vehicle
- Drivers are trained to look to this location for information about the rear scene.

While we are not certain that this is the best location for all cases, we felt that it was worth evaluating. The following sections describe the major components in further detail.

<u>Cameras</u> – Our initial demonstration activities had used CCD based cameras. While they were bulky and used a great deal of power, they offered excellent performance in terms of resolution, low light level sensitivity, and color. In the time since we completed our initial developments, CMOS camera technology has significantly advanced in terms of performance.

CMOS camera technology offers a more integrated and lower power solution than CCD imagers. This results in lower cost and smaller cameras. In addition, the sensors are available with a simple digital interface that reduces the size and complexity of the processing electronics.

Based on these advantages we decided to develop custom camera boards using VLSI Vision LTD's VV6404 CMOS image sensor. The custom boards allowed us to develop extremely small cameras that met our interface requirements.

Display – Given our success with LCD technology in our earlier efforts and the general acceptance of this technology in the automotive market, we elected to continue to apply this technology. We were, however, able to leverage two recent advancements.

The first is the availability of wider aspect ratio displays. The panoramic video image shows a very wide field of view in the horizontal axis, but a relatively small field of in the vertical direction. This results in an image with a rather wide aspect ratio.

Our first vehicle used a 3:4 aspect ratio display. When we mapped the panoramic image onto this display we were only able to use 50% of the display area for the video. Recently, displays have been released in a 9:16 aspect ratio. Mapping our image onto this format resulted in our using 66% of the display for our video image - a significant improvement.

The second improvement to the display was in the interface. At the time we selected our first display, smaller LCD's were only available with analog interfaces. As much of the image processing is performed digitally, this required a D/A conversion. Newer displays are available with a digital interface - reducing the complexity of the electronics and improving the noise performance of the system.

In the end we selected a 18 cm diagonal, wide-VGA display manufactured by Sharp. This provided the best fit of size, resolution, aspect ratio, and cost for our system.

Electronics – It is in the electronics that the largest differences between the old and new systems lie. The original system was required to deal with analog cameras and an analog display interface. In addition, the original system used analog video standards to transmit images from one sub-module to the next. As much of the image manipulation was performed digitally, this required multiple analog to digital and digital to analog conversions - increasing the complexity of the system while reducing the image quality. The new design offers the following features:

- Completely digital system, from camera to display - improving image quality and reducing signal noise
- Integrated, common processing for video manipulation and graphical overlays
- Single-board design reducing system interconnect and size for increased reliability and lower package volume
- Hardware-accelerated bilinear interpolation of pixel data for smooth scaling, stretching, and rotation of video data and other graphical images
- Embedded 32-bit microprocessor for real-time control of video processing and graphical overlay functions.

A functional block diagram of the electronics is shown in Figure 8. The sensor data is written into a large texture memory under hardware control. A general purpose microprocessor then sets up block transforms from the texture memory into a frame buffer by setting the desired rotation, scaling, and translation coefficients. The hardware then performs the commanded transforms, forming a composite image in the frame buffer. Once all of the required transforms are complete, the hardware then displays the final image on the LCD.

CURRENT DEVELOPMENT STATUS – We have recently completed the development of our new prototype panoramic rear vision system and installed prototypes in several vehicles for further technical evaluation. We are working with several automotive manufacturers to determine technical, cost, and schedule requirements for potential production opportunities.

SYSTEM PERFORMANCE – One of the goals of this activity was to demonstrate an improved performance as a result in technical developments. The following table summarizes the technical performance of the system:

Table 2. System Performance Parameters

Parameter	System Performance
Screen Aspect Ratio	9:16
Effective Screen Size	5.3 cm X 16 cm
Effective Screen Resolution	320X854
SNR	32 dB
Graphics	Hardware Accelerated
Update Rate	30 Hz
Latency	60 ms
Electronics Volume	300 cm^3

FUTURE WORK

While our prototype has been successful in demonstrating the feasibility and utility of panoramic rear vision, the development activities are far from complete. In order to successfully sell this concept into production we will need to address both the cost effectiveness of the system as well as redesign the electronics for production. The issues relating to each of these tasks are described in the following sections.

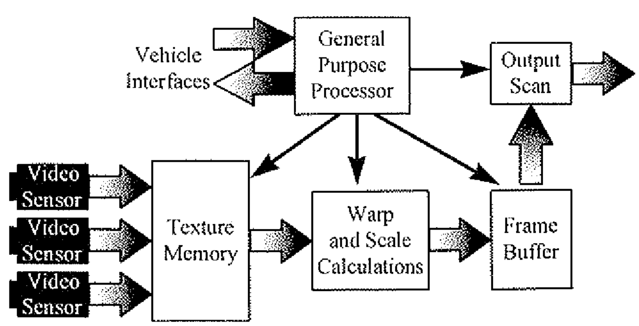


Figure 8. Electronics Block Diagram

ADDITIONAL FEATURES – Displaying full motion color video required the use of a relatively expensive display technology. The advantage of this display technology is that it can be adapted to multiple functions to improve the cost effectiveness of the system. In addition to displaying panoramic video images, the display can be used to present vehicle status or navigation information to the driver.

This is where the decision to use a common graphics/ video processing architecture begins to have advantages. The same hardware we used to perform the video processing can be used to accelerate texture-mapped graphical representations ranging from simple instrumentation to complex moving maps.

Future development efforts will focus on using this capability to add features to the rear vision system. We will begin by adding the functionality associated with a traditional instrumentation cluster and continue by developing context-sensitive formats for display of vehicle status and control of other vehicle sub-systems. By leveraging the multi-functional nature of the display we can use the system to address a variety of control and informational needs.

PRODUCTION ISSUES – As stated earlier, the prototype was not developed with the intent to transition it directly to production. Our efforts to turn this into a commercially viable product will focus on a combination of performance improvement and cost reduction.

The implementation of the electronics is one area where we will focus on cost reduction as well as improving EMI and EMC compliance. The custom digital logic required to accelerate the texture calculations needed to merge the video was implemented using relatively expensive memory technology and a reconfigureable part. Significant cost savings will be achieved by implementing the logic in a custom component and by using a more cost effective memory technology.

Progress can also be made in improving the performance of the camera. While CMOS camera technology is inherently lower cost than the alternative and has several performance advantages in terms of blooming, its noise performance - particularly at night needs to be improved. Future generations of CMOS cameras will implement features such as micro-lensing to improve the low light level sensitivity.

A final area where we plan to make progress is in the optics. We are currently investing in the development of low cost plastic optics. This new technology allows the cost effective implementation of lenses that use a combination of diffractive and refractive elements that are quite cost effective and low weight.

CONCLUSION

We believe the future of automotive information systems lies in the successful integration of multiple sources of information for presentation to the driver with the intent of improving safety and reducing work load. We have successfully demonstrated applying this concept to the rear vision system - replacing three mirrors with a single integrated display.

Daily advances in electronics and display technology continue to improve the cost effectiveness of these systems. We believe that it is a matter of when, as opposed to if, electronic information systems will become commonplace in automotive applications.

REFERENCES

1. W.J. Burger, "Evaluation of Innovative Passenger Car and Truck Rear Vision Systems", SAE 740965

CONTACT

Rich Hicks received both his master's and bachelor's degrees in electrical engineering from the State University of New York at Binghamton. He has spent the past eighteen months working at Donnelly on the development of electronic rear vision systems. Prior to his work at Donnelly, he spent six years at Sanders, a Lockheed Martin Company where he engaged in research and development of cockpit controls and display subsystems.

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Ken Schofield received his bachelor's degree in mechanical engineering from the University of London and his master's degree in engineering design from the Loughborough University in England. He has spend the past 18 years in various rolls at Donnelly.. He joined Donnelly as an engineering manager at Donnelly's Irish plant and has spent the past 14 years managing Donnelly's advanced product development group. He is currently the vice president of advanced engineering at Donnelly Electronics

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Paul Tarnow received his bachelor's degree in electrical engineering technology from Northern Illinois University in DeKalb, IL. He has spent the last two years working at Donnelly on the development of electronic rear vision systems, smart sensors and test systems. Prior to his work at Donnelly, he spent seven years at Dukane Corporation in St. Charles, IL. as a test systems engineer.

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Mike Veiseh received bachelor's of science degrees in both electrical and computer engineering from Arizona State University. He has spent the past 3 years working in the automotive electronics department at Donnelly developing embedded microprocessor and microcontroller systems. Prior to his work at Donnelly, Mike worked for 6 years at Brunswick Corporation where he was responsible for the development of computer controlled bowling center systems.

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LYNAM EXHIBIT B

WARD'S AutoWorld

Looking Back to the Future -- How hard can it be to eliminate a driver's blindspot?

TOM MURPHY
Ward's AutoWorld, May 1, 1998 12:00 PM

Automotive innovators have tackled plenty of safety issues over the years from softening the impact of collisions to providing greater control during emergency braking. A satellite high above the Earth can pinpoint, within a matter of meters, the location of a stranded motorist.

Still, unless a driver turns his head at least 90 degrees, he cannot tell with any certainty whether a vehicle is in an adjacent lane. It surely contributes to road rage, as well as potential accidents. In one study, the National Highway Traffic Safety Admin. (NHTSA) estimates lane change and merging accidents account for 16% of all major collisions.

Today, suppliers are pursuing numerous technologies to eliminate the pesky blind-spot, from more easily adaptable aspheric side mirrors to advanced - and more expensive - cameras and sensors designed to detect any object behind or beside a moving vehicle.

The technologies are not terribly new, but they have been refined over the years - and costs are coming down. In addition, NHTSA, which allows only passenger side mirrors to be convex or aspheric, now considers allowing aspheric mirrors on the driver side.

Convex mirrors are bent, making objects appear smaller and farther away. Aspheric mirrors are flat, but the outer edge is angled outward. Both mirrors significantly expand a driver's field of vision. Convex mirrors cost slightly more than flat ones, while aspheric mirrors can be several times more expensive, depending on the curvature.

A Dutch research group is preparing a report for NHTSA, due this June, on how European drivers interact with aspheric and convex mirrors, which are used on both sides of vehicles in that region, says Stephen Kratzke, director of NHTSA's Office of Crash Avoidance Standards.

"If we get information that they (aspheric mirrors) will work, then we would allow them," Mr. Kratzke says. "We want to know if people will catch on quickly to how you use them to expand your field of view."

NHTSA doesn't take this stuff lightly. The agency currently requires that driver-side mirrors be flat, partially because motorists complained of headaches when NHTSA first

allowed convex passenger-side mirrors in 1983. Mr. Kratzke says it's been a long time since NHTSA heard such complaints.

Suppliers are not counting solely on aspheric mirrors as the future in rear-vision automotive applications in the U.S. Many are investing in sensors and digital camera technology to tell a driver whether an adjacent lane is clear.

Donnelly Corp., which makes 95% of the prismatic mirrors used on U.S. cars today, is delivering a three-camera "panoramic vision" system to replace the mirrors in a concept vehicle being produced by a customer within the next year.

The system replaces the side mirrors with tiny digital cameras, about the size of a golf ball, and adds a third camera in the rear of the vehicle. All three images are converged into one, which can be displayed for the driver on a screen on the instrument panel.

The system provides full vision of everything behind and beside a moving vehicle. It nullifies the need to turn your head, for those people who don't trust mirrors.

Donnelly developed the system with Vision Group plc, its partner in Edinburgh, Scotland. Vision Group provides the CMOS imaging chip driving the system.

Are drivers ready for it? "We have the functionality," says Ken Schofield, Don-nelly's executive director of advanced engineering. "The question is price and application. It requires a change on the part of drivers."

If NHTSA struggled with convex mirrors, it surely will view camera vision with extreme caution because of the potential distractions for drivers.

"Camera vision is like having a TV on, to the extent that it's taking the driver's attention off the road," Mr. Kratzke says. Still, he concedes, drivers already are looking at mirrors in three different places. Combining the images into one central location could be an improvement.

But government acceptance isn't the only hurdle. Cost is a major consideration. Mr. Scho-field estimates the pricetag could be $1,000, going down to $350. Eventually, costs could be comparable to existing mirrors, depending on the features and configurations.

"It's just too expensive," says Ken LaGrand, executive vice president for mirror supplier Gentex Corp., which is developing rear-vision systems with its partner, Photobit Corp. of Pasadena, CA. "As a consumer, I would like it on my vehicle, but my feeling is it's probably got to come down in price to a few hundred dollars. That might be a little optimistic," he adds.

Mr. LaGrand says it will be several years before a U.S. vehicle is equipped with rear-vision cameras. Meantime, Gentex is pursuing aspheric mirrors, which started out in

Scandinavia 10 years ago and are expected to outnumber flat and convex mirrors in Europe within the next few years.

Gentex recently announced it will supply the world's first aspheric exterior electro-chromic, or automatic-dimming, mirrors for several Mercedes-Benz luxury sedans.

Another method of eliminating blindspots is with sensors that beep to warn drivers that the lane they are moving into is occupied. Several suppliers, including Donnelly and Gentex, are developing such systems.

Autosense Ltd. of Denver, CO, has teamed with Siemens Components Inc. to develop SideMinder, which uses sensors located near the rear taillights to alert a driver, with a flashing warning light, if a vehicle is in the right or left blindspot.

Alirt Advanced Technology Products, a small Canadian company, is planning commercial delivery of a battery-operated aftermarket blindspot sensor this year.

LYNAM EXHIBIT C

Donnelly

2000 COMPANY PROFILE

Donnelly

Donnelly Corporation is a technology driven, customer focused automotive supplier known for offering the most advanced technologies for automotive mirror systems, window systems and electronically sophisticated sensor systems to customers around the world. Donnelly and its affiliates employ more than 7,000 people in the U.S. and twelve other countries in North America, South America, Europe and Asia.

Donnelly Facilities Worldwide
(including joint ventures and affiliates)

NORTH/SOUTH AMERICA

Holland, Michigan
Detroit, Michigan
Grand Haven, Michigan
Norton Shores, Michigan
Holly, Michigan
Newaygo, Michigan
Mt. Sterling, Kentucky
Tucson, Arizona
Monterrey, Mexico
São Bernardo do Compo, Brazil

EUROPE

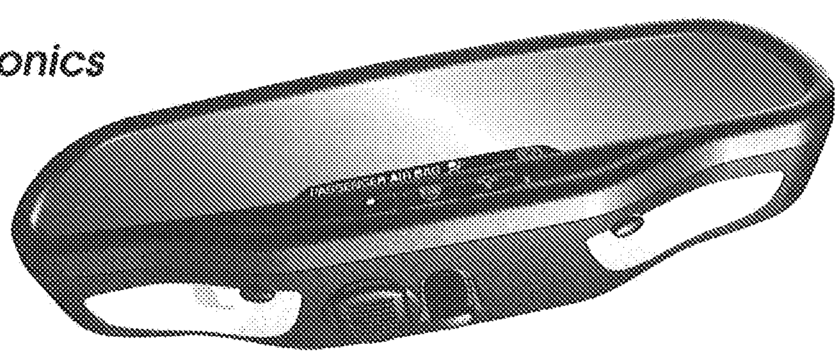
Gotëborg, Sweden
Manorhamilton, Ireland
Naas, Ireland
Longford, Ireland
Schleiz, Germany
Collenberg, Germany
Dorfprozelten, Germany
Langres, France
Nanterre, France
Torino, Italy
Barcelona, Spain
Palmela, Portugal

ASIA

Yantai, China
Shanghai, China
Shunde, China
Tokyo, Japan
Penang, Malaysia

Donnelly has over 30 facilities worldwide.

What's The Buzz? . . . Electronics

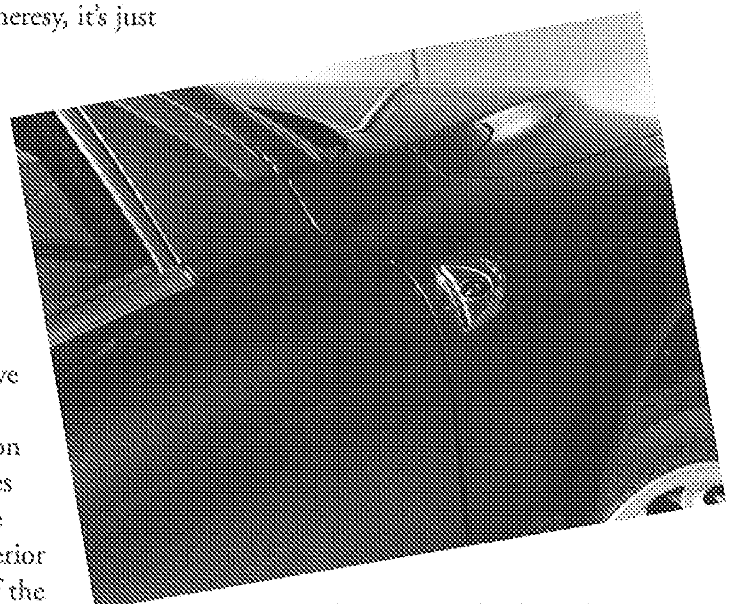


A hands-free microphone and convenient push buttons mounted in the interior mirror will give drivers easy access to the OnStar® roadside assistance call center. Donnelly will start production of these advanced mirrors during the summer of 2000.

During 1999 Donnelly won a major new business commitment from General Motors to build interior mirrors that contain advanced electronics to support GM's OnStar® consumer telecommunications service. The OnStar® package is a good example of how automakers are beginning to view mirrors as an attractive place to locate electronics.

But there's more to Donnelly's electronics story than mirrors. In fact, over the long term we're hoping to use electronics to make our own mirror products obsolete. That isn't heresy, it's just smart thinking.

Picture This



Replacing outside mirrors with smaller, more aerodynamic camera pods can cut wind drag by 15%!

For nearly a decade, Donnelly has been the pioneering leader in the development of camera vision systems that ultimately can replace mirrors on cars and light trucks. Why? Because we believe camera vision offers a better approach. Camera vision eliminates blind spots and frees automotive designers from the need to incorporate bulky exterior mirror housings on vehicles of the future. That dramatically reduces wind resistance and improves fuel economy.

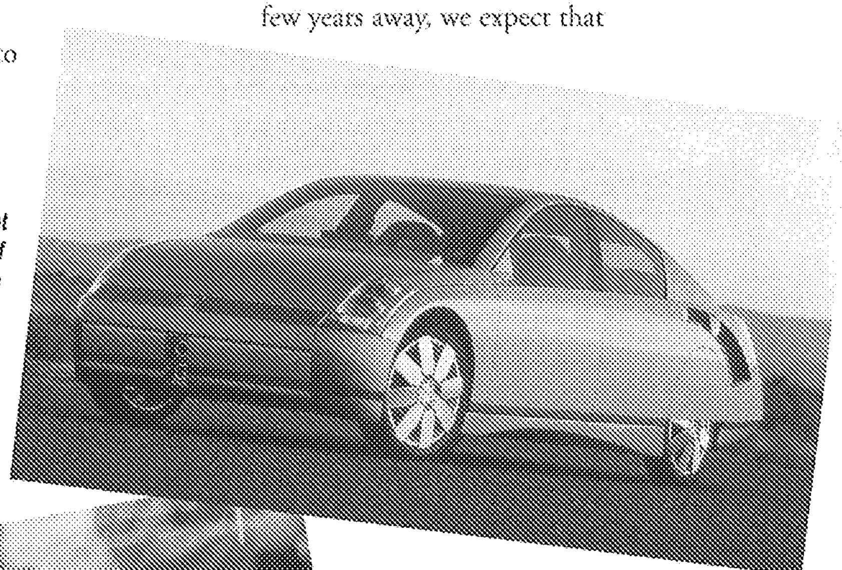
Late in 1999, GM introduced its ultra high-mileage *Precept* concept vehicle, which included a sophisticated Donnelly camera vision system. Donnelly's unique system is built around proprietary software that

merges the digital images from three or more separate cameras into a single panoramic image. Through that image, drivers have a clear, unified view of the rear and sides of the vehicle.

By eliminating the need for outside mirrors on the *Precept*, GM engineers estimate they were able to reduce the vehicle's drag by about 15 percent. That's better than getting your overweight brother-in-law out of the back seat!

In addition to the camera vision system, Donnelly extended its technologies a step further on the *Precept* program. Built into the instrument panel of the vehicle is a single-screen display that shows the camera vision image and other essential vehicle information—such as speed, fuel levels and other data—that traditionally have been shown on separate gauges on the instrument panel. Donnelly designed and developed the central display, which provides an easy-to-read information source and helps reduce overall vehicle weight.

The *Precept* system was just one of the camera vision systems Donnelly delivered last year to automakers in North America, Europe and Asia. While full camera vision systems on production vehicles may still be a few years away, we expect that supplemental camera vision aids—for things like driving in reverse or trailer towing—will make their commercial debut over the next year or two.



GM's Precept concept car got plenty of attention at the Detroit Auto Show. It is outfitted with a three-camera vision system produced by Donnelly.

Images from the three cameras are merged into a single panoramic rearward scene that is displayed along with other vehicle information like speed and typical instrument panel readouts.

LYNAM EXHIBIT D

http://www.gm-press.com/HU/site/article.php?aid=532

GM Precept: Concept Vehicle with Lowest Drag

2000.01.05.

DETROIT - Opel's parent company General Motors will unveil the Precept, a fully functional hybrid electric vehicle with the lowest drag coefficient (C d = 0.163) ever recorded for a five-passenger, four-door family sedan, at this year's Detroit Motor Show (January 15 – 23).

Parallel hybrid drive – Advanced battery systems – Extensive use of aluminum

The Precept is powered by an electric motor driving the front wheels and a turbo diesel engine with common-rail direct-injection driving the rear wheels. The parallel-hybrid propulsion system, managed by sophisticated electronic controls, helps the Precept approach its target fuel consumption of 80 miles per gallon (2.94 liters per 100 kilometers).

Two of the world's most advanced battery systems are being explored for use in the Precept - the world's first application of lithium polymer batteries for hybrid vehicle propulsion, and a new generation of compact nickel metal hydride batteries. Aluminum is used extensively throughout the vehicle's body and chassis to reduce mass.

The Precept is the latest demonstration of GM's capability and commitment to developing efficient and affordable environmentally compatible vehicles. It evolved as a result of GM's involvement in the Partnership for a New Generation of Vehicles (PNGV), a joint effort between the US Government and the US auto industry that began in 1993. The specific aims of this partnership are lower emissions and significantly improved fuel efficiency without compromising safety, performance, affordability, or utility.

Whereas the PNGV parameters were the catalyst for Precept, the high-efficiency architecture and the propulsion system are a unique solution created by GM. Moreover, the same technologies developed in the Precept program have been leveraged by other advanced vehicles at GM, including the high-efficiency, low-emissions Opel G90 shown at the Frankfurt Motor Show last September.

Precept Feature Highlights: Technologies of the Future Today

The dual-axle regenerative, parallel hybrid propulsion system of the Precept features a 35 kW three-phase electric motor driving the front wheels and a three-

cylinder,
1.3-liter turbo diesel engine (40 kW/54 hp) with common-rail direct-injection driving the rear wheels. Multiple energy-conversion devices are used for propulsion because that facilitates operating each in its zone of optimum efficiency. Sophisticated electronic controls interpret the driver's commands and manage every aspect of the propulsion system's operation.

The brain of the entire hybrid propulsion system is a PC processor-based controller. This 32-bit, 266 MHz device conducts a two-way dialogue with the following equipment: accelerator pedal, brake pedal, gear shifter, energy management system, electric traction system, multi-purpose unit, diesel engine controller, transaxle controller, thermal system controller, and brake controller. It makes snap decisions to optimize all operations, such as the highly intelligent heating and cooling system. Specifically, the system moves otherwise wasted thermal energy automatically to where it's needed - it even anticipates when fog could form on the windshield and works to prevent it. Throughout the Precept, forty-seven distributed computer modules provide smart control to make this the world's most computerized vehicle.

Key Component: Computer-Controlled Automatic Gear Shifting

A key component of the hybrid powertrain is a unique, high-efficiency, automatically shifted manual transaxle. Fifth and reverse gears were eliminated (reverse operation is provided by the electric traction system in the front of the vehicle). Gear shifting via clutch was converted to an automatic, computer-controlled operation.

As a result, the diesel engine can be started in any gear, and skip shifting is also possible. In addition, the time required for a gear change, or to start the engine, is about 0.7 seconds. Most importantly, efficiency losses through this transaxle are particularly low.

Another key benefit of the dual-axle, parallel-hybrid approach is that it offers maximum use of regenerative braking through all four wheels. When the driver lifts off the accelerator or taps the brake pedal, unwanted momentum is automatically converted to electrical energy and used to recharge the battery pack located under the front seat. That alone amounts to more than 0.5 l/100 km in combined city-highway driving, helping the Precept approach its target of 2.94 l/100 km. An ingenious multi-purpose unit handles regenerative braking through the rear wheels in addition to performing five other functions: it contributes 10 kW of propulsion power when maximum acceleration is desired, it starts the rear-mounted engine, it powers the air-conditioning compressor when the engine is at rest, the engine can drive it as a generator to recharge the battery and it is used to synchronize the gears for clutchless shifting.

Architecture: Lightweight and Ultra-Efficient

The Precept uses a light, stiff space-frame body structure constructed of aluminum stampings, extrusions and castings. Exterior panels are made of aluminum and composite materials. Bumper beams are fabricated with carbon fiber.

Since the weight carried by the front tires has been significantly reduced, no power steering is necessary. Computer-controlled air springs maintain a level ride height irrespective of passenger and cargo load changes. The springs' source of compressed air can be tapped to inflate the Michelin Proxima low rolling-resistance radial tires. The Precept's aluminum wheels each weigh only 3.8 kg , distinguishing them as the world's lightest 16-inch wheels. The friction brakes for the Precept save even more weight. An advanced brake-by-wire system uses a small electrically powered hydraulic pump located in close proximity to each brake caliper.

Aerodynamics Record: World's Best Four-Door Drag Coefficient

Maintaining a controlled ground clearance in conjunction with the use of a flat underbody, rear cooling air entries and exits, and other aerodynamic features - along with extensive wind-tunnel tuning - has resulted in the lowest drag coefficient ever recorded for a five-passenger, four-door family sedan (C d = 0.163). So efficient is the Precept's shape that just the addition of conventional outside rear-view mirrors would increase drag by more than 17 percent. Consequently, the Precept employs two tiny cameras instead of outside rear-view mirrors which, when combined with a third rear-facing camera located inside the rear window, produce an integrated panoramic rear view on a reconfigurable LCD display easily viewed by the driver.

Interior: Attractive, Functional and Driver-Oriented

The Precept's interior is nearly as futuristic as its exterior and mechanicals. Advanced interior trim materials not only save additional weight, they also provide added convenience and an inviting appearance. The ultra-light front seats consist of powder-coated steel and aluminum frames with a bare minimum of foam padding and trim materials. A Driver Control Center provides a unique driver-vehicle interface used to operate the car. To start and drive the car, no mechanical key is needed. Instead, the driver enters a five digit security code using the electronic key pad positioned below the display screen, hits the RUN button, and shifts the vehicle out of park and into forward or reverse gear using another set of push buttons.

A smart switch in the control panel operates like a mouse for the laptop computer docked at the top of the instrument panel. It is used to scroll through a menu displayed on the laptop screen. The screen is positioned far forward just under the windshield's base, so minimal refocusing is necessary when shifting between a view of the road and a check of the instruments. Three distinct categories of

information are presented: a view to the rear supplied by the three video cameras; vehicle operating data, such as speed and fuel remaining; and secondary entertainment and climate control system parameters.

LYNAM EXHIBIT E

http://www.theautochannel.com/news/2001/09/10/029252.html

Donnelly PanoramicVision on Renault Talisman Concept Car At Frankfurt

Renault Vel Satis will also feature Donnelly interior electrochromic rearview mirror and exterior electrochromic powerfold mirrors.

FRANKFURT, Germany, Sept. 10 2001

Donnelly Corporation and Renault have teamed up to demonstrate new technology at the 2001 Frankfurt Motor Show, September 11-23. Donnelly is supplying enhanced driver visibility and safety products on Renault's vehicles.

Donnelly's next generation PanoramicVision(TM) system is demonstrated on the Renault "Talisman" concept car. There are no mirrors on the car. Instead, this system digitally merges the images from three cameras to relay a seamless panoramic view of the area behind and around the vehicle. The view is displayed on a screen located on the upper part of the dashboard. The screen also provides information on navigation, the sound system, the heating and cooling system, and the vehicle's warning and security system.

In addition, Donnelly has other advanced products on Renault's production vehicles featured at the show. Renault's Vel Satis luxury car is equipped with a Donnelly interior auto-dimming electrochromic rearview mirror, which houses both a humidity and rain sensor. This new luxury car also features Donnelly's auto-dimming electrochromic outside mirrors with a powerfold feature that allows the vehicle to be parked safely in tight spaces. Renault's Avantime, displayed at the show, will also feature Donnelly interior auto-dimming rearview mirrors.

"Donnelly is very pleased to work with Renault to demonstrate our leadership in vision technology," said Frank O'Brien, vice president, Corporate Planning. "Our technology will bring an improved level of safety and styling to the vehicles of tomorrow."